SOIL TEXTURE, PARTICLE SIZE DISTRIBUTION, SPECIFIC SURFACE AND CLAY MINERALS

We will assess the physical realm of soil science in a piece-wise fashion starting with the physical phases of soil, -- **a single grain concept** -- progressing to complex flow dynamics and other application process.

This is start of the single grain view

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The solid phase of soils consists of discrete units, called primary soil particles. These particles vary widely in size, shape, and composition. Thus, soils are classified according to the "particle-size distribution" or "texture" of the mineral solids

Particle sizes are divided into different ranges called "soil separates." There are several classification systems available (see Fig. 3.1 on page 41 of textbook), but------- **we will use the USDA System.**

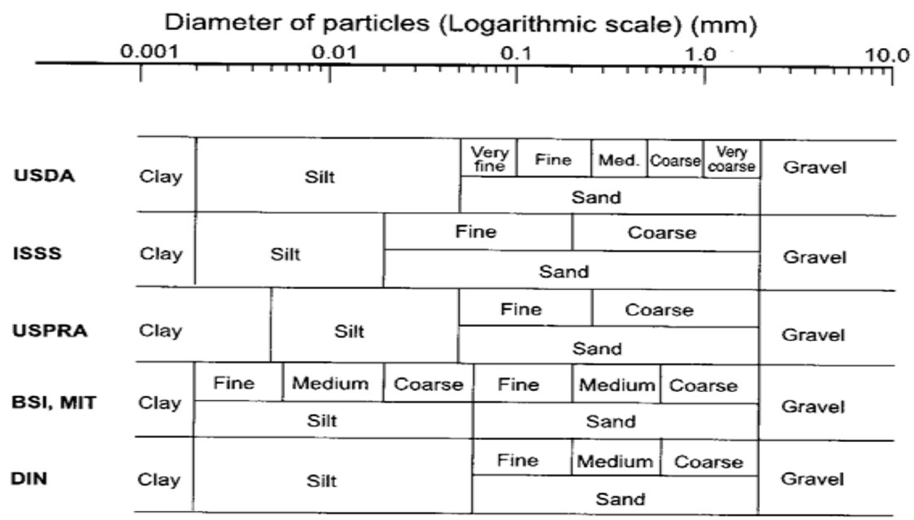


Fig. 3.1. Several conventional schemes for the classification of soil fractions according to particle diameter ranges; U.S. Department of Agriculture (USDA); International Soil Science Society (ISSS); U.S. Public Roads Administration (USPRA); British Standards Institute (BSI); Massachusetts Institute of Technology (MIT) ; German Standards (DIN).

Sieve Sizes (mm)	Fraction
> 2	Rock
1	Very coarse sand
0.5	Coarse sand
0.25	Medium sand
0.10	Fine sand
0.05	Very fine sand
0.002	Silt
< 0.002	Clay

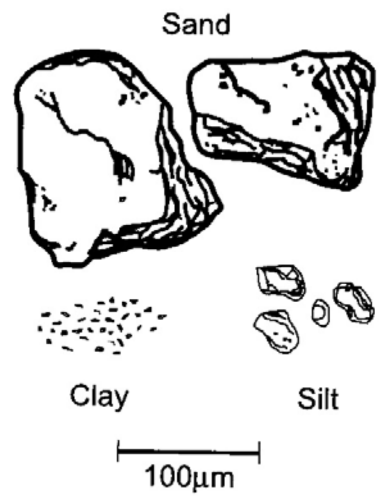
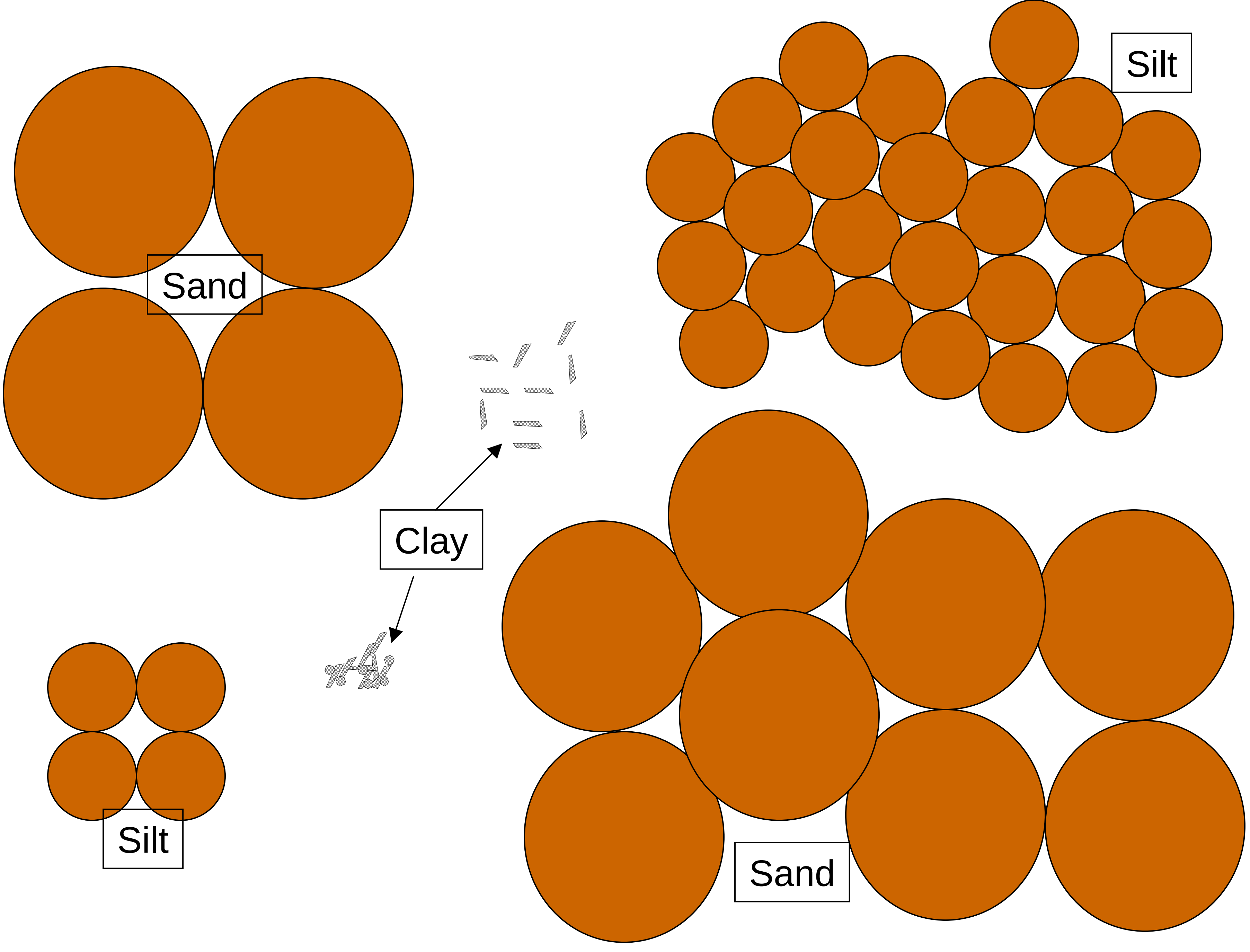
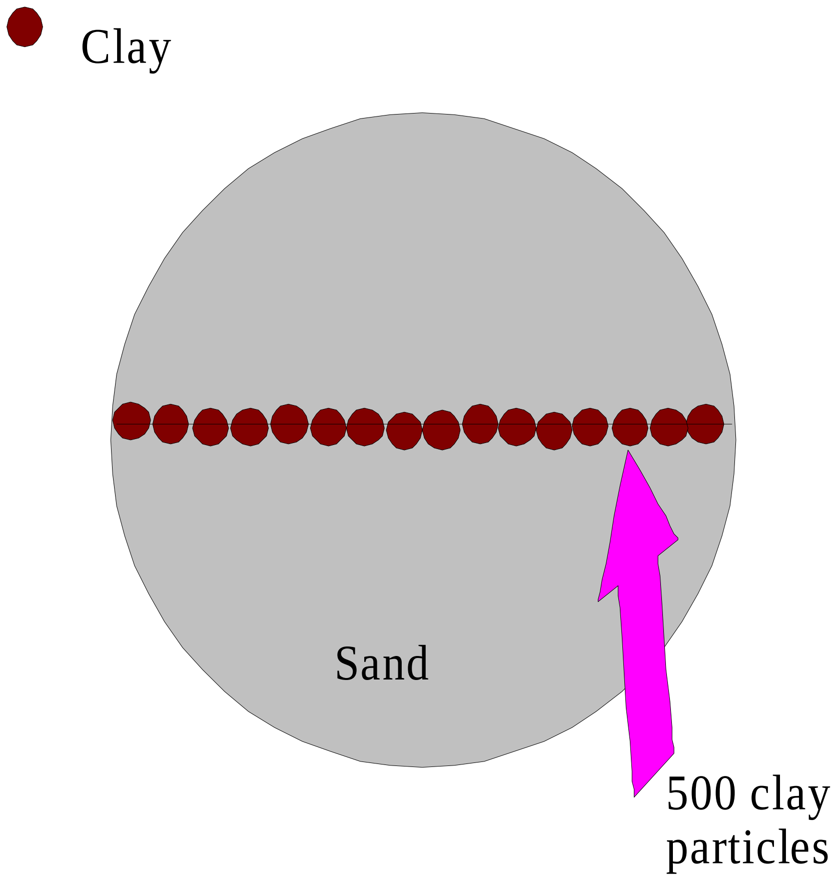


Fig. 3.2. A visual representation of the comparative sizes of sand, silt, and clay particles.


Silt
Sand
Clay
Sand
Silt



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0.10	Fine sand
0.05	Very fine sand
0.002	Silt
< 0.002	Clay

There should be 500 clay particles around a single grain of sand. This is because the diameter of sand ÷ diameter of clay is 1 mm/0.002 mm = 500.

Given its size, clay can absorb more water molecules and cations (fertilizer such as K, Ca, Mg, etc).

Particle-size analysis (PSA) or "mechanical analysis“ is the determination of the amount of the various soil separates in a soil sample.

For soil particles larger than 50 µm (0.05 mm) PSA is done with sieves.

For soil particles < 0.05 mm PAS is determined by sedimentation -- with a **hydrometer or pipette**. With this method, it is assumed that the particles are spherical (may be true for sand and silt---but---clays are flat or plate-shaped or even rods).

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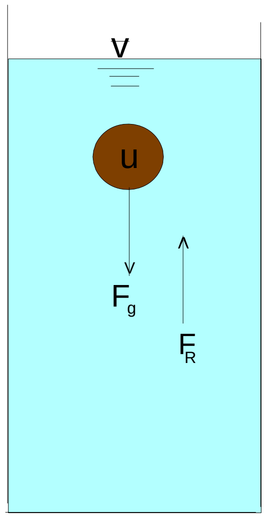
0.05	Very fine sand
Sedimentation	
0.002	Silt
< 0.002	Clay

Stoke's Law

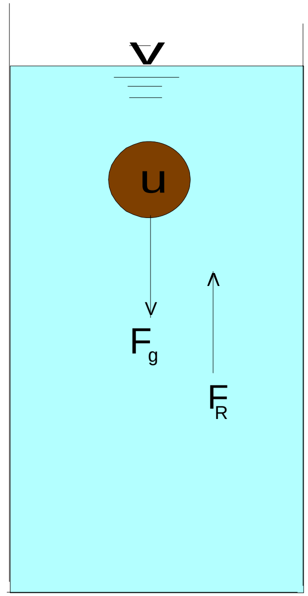
- A particle falling through a vacuum will continue to accelerate because of gravitational forces and the lack of resistive forces.

- **The magnitude of the friction force (F_r), acting on a particle falling through a fluid (water, air, etc.), is proportional to the velocity of the particle.** The frictional force resisting the fall increases as the velocity increase.

- When the frictional force (which we noted increases with velocity) equals the gravitational force (g, a constant, 9.8 m/s^2) the particle falls at a constant velocity (termed the terminal velocity).



u = Speed of particle
$F_g = F_r$ resistance/drag



The downward force due to gravity, F_g, is:

$$F_g = (4/3\ \pi r^3)(\rho_s - \rho_f)\ g$$

Note: $F = ma$
$a = g$, gravity

where:
r = radius of particle, (m, L)
ρ_s = particle density (Mg/m^3, M/L^3)
ρ_f = density of the fluid (Mg/m^3, M/L^3)
g = the acceleration of gravity (m/s^2, L/T^2)

ρ = Mass/Volume
Volume = $(4/3)\pi r^3$

u = Speed of particle
$F_g = F_r$ resistance/drag

The resisting or drag force, F_r, is:

$F_r = 6\pi\ \eta r u$ = Stoke's Law

where:
η = viscosity of the fluid ($N\ s/m^2$)
u = velocity of the particle (m/s)

$$F_g + F_r = 0$$

$$(4/3)\pi\ r^3 g(\rho_s - \rho_f) - 6\pi\ \eta r u = 0$$

$$6\pi\ \eta r u = (4/3)\pi\ r^3 g(\rho_s - \rho_f)$$

$$\boxed{u = (2/9)(r^2 g/\eta)(\rho_s - \rho_f)}$$

DIMENSIONAL ANALYSIS

- The word dimension denotes the physical nature of a quantity. For example, distance has units of feet, meters, etc., but in either case it has dimensions of length (L).
  - Other examples:
    - Area = L^2 — m^2 or ft^2
    - Velocity = L/T — m/s or ft/s
    - Mass = M — g, kg or lb

- Dimensional analysis is used to check an equation for proper balance.

- Example, the distance (x) traveled by a car in time (t) if the car starts from rest and has a constant acceleration (a) is described as follows:

    - $X = (1/2)at^2$

- Writing the units of x, a, and t in a dimensional analysis form one can check the equation as follows:
    - $L = (L/T^2)T^2$
    - L=L

One way to measure PSA is to take a known volume of sediment from a suspension at a given depth at several time intervals--after sedimentation begins as previously noted this is the **pipette method**.

Thus, we need to know the time, t, it takes for a particle of diameter, d, to settle to some depth, h.

$$u = \text{distance}/\text{time} = h/t$$

$$h/t = (1/18)(d^2 g/\eta)(\rho_s - \rho_f)$$

$$t = 18\ \eta h/d^2 g(\rho_s - \rho_f)$$

Another method is to use a **hydrometer** to measure the density of the sediment at different time intervals.

A **new approach** for measuring particle size distribution is to use a **laser techniques**. This techniques uses laser diffraction or forward light scatter to measure grain size distribution.

$$u = (2/9)(r^2 g/\eta)(\rho_s - \rho_f)$$

$$h/t = (1/18)(d^2 g/\eta)(\rho_s - \rho_f)$$
$$t = 18\,\eta h/d^2 g(\rho_s - \rho_f)$$

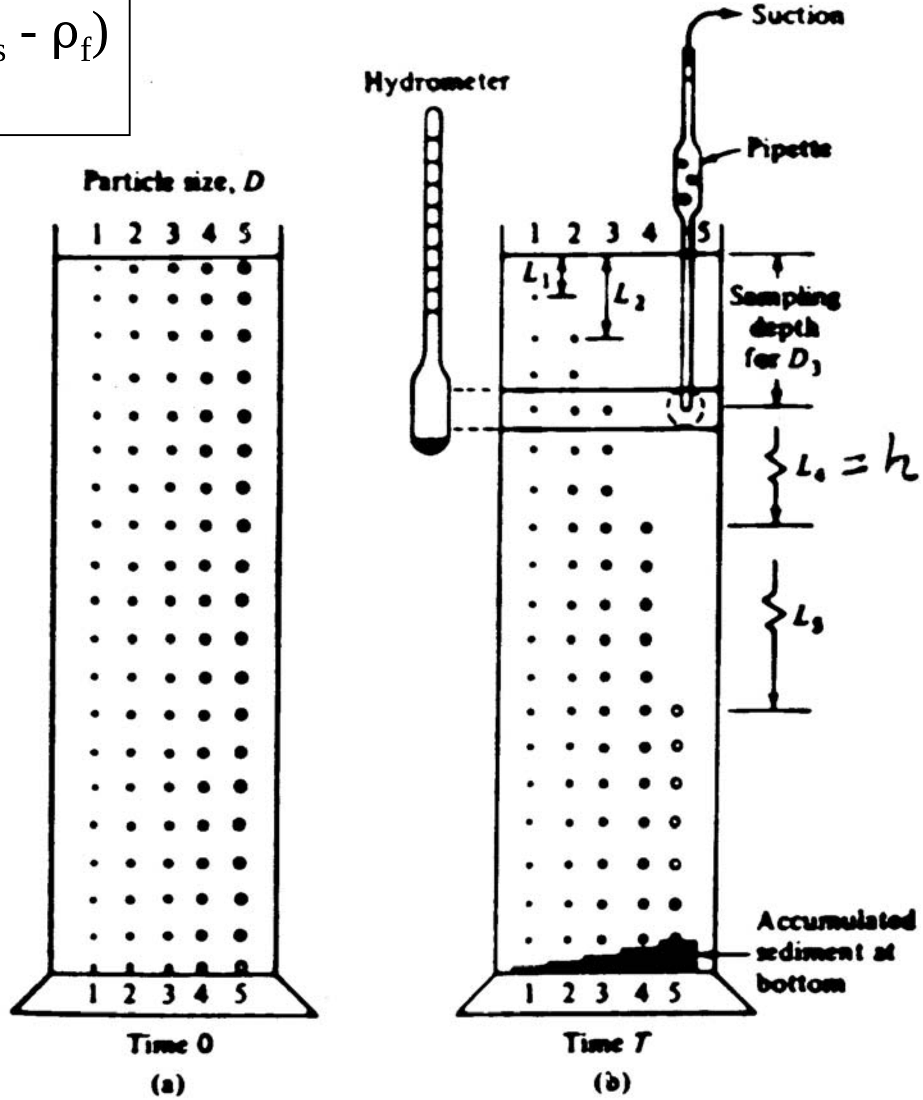
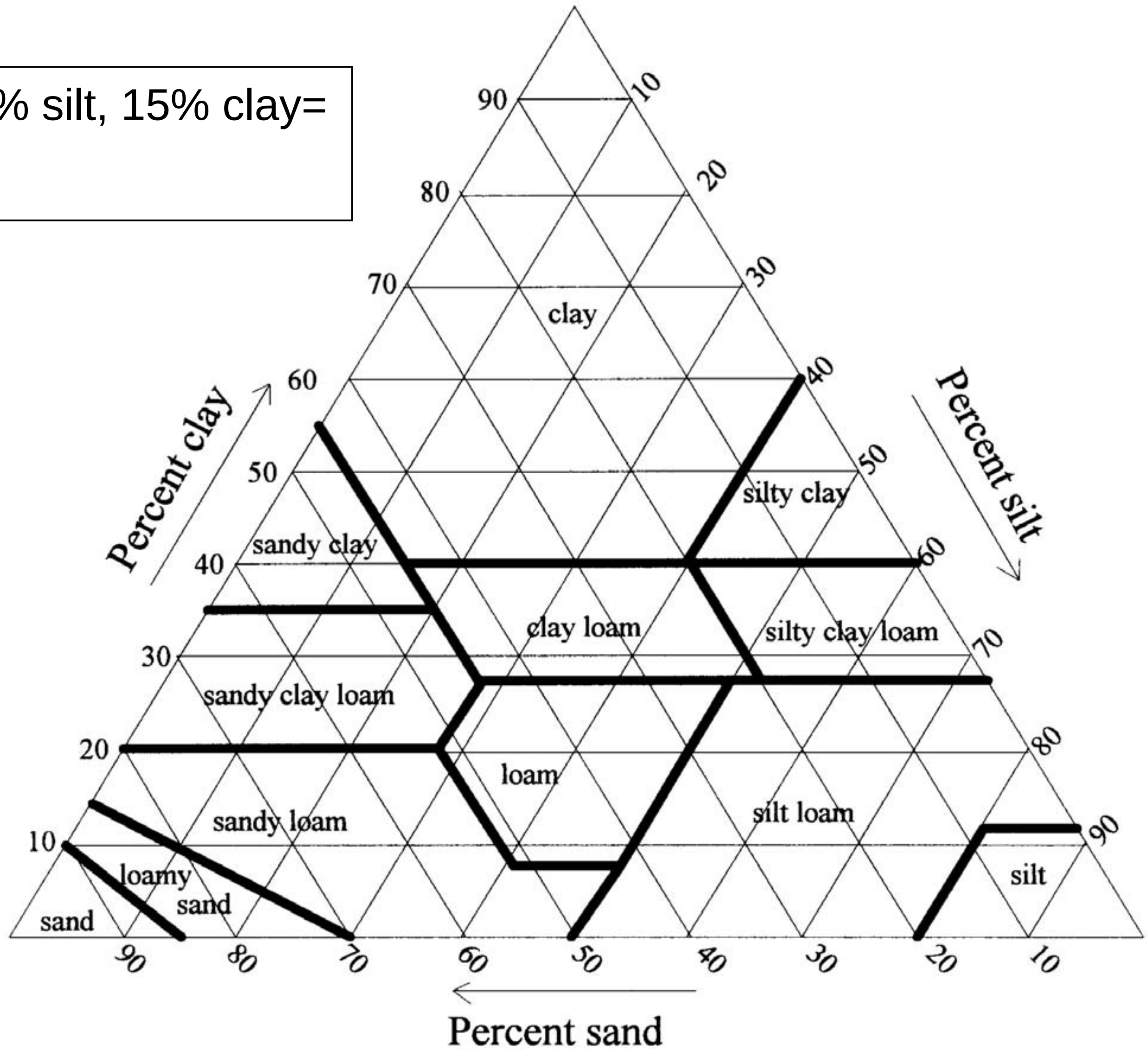
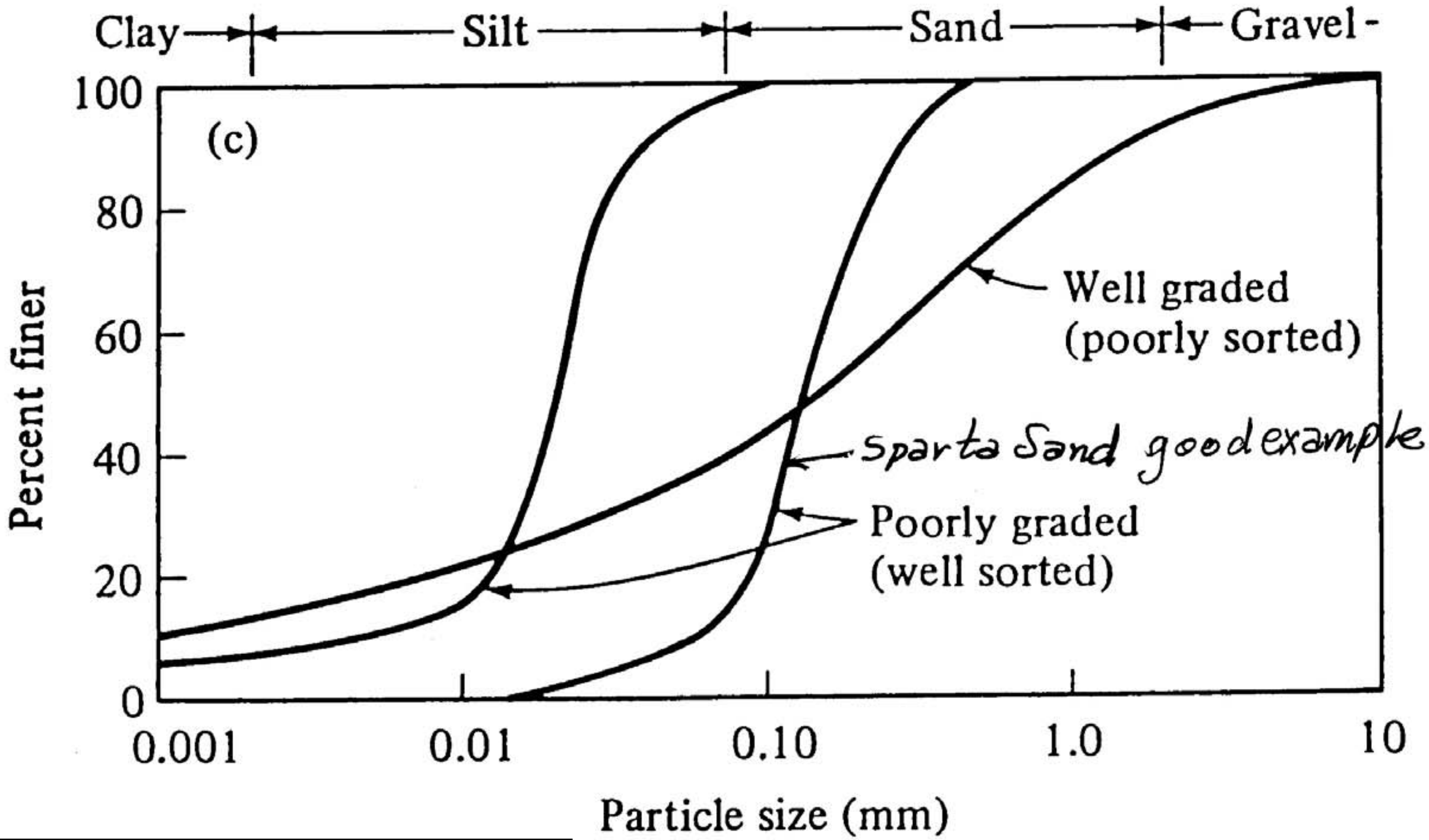


Figure 7.1 Schematic representation of sedimentation of different particle sizes, and sampling for particle size analysis. (Modified after Chu et. al. [14].)

45% sand, 40% silt, 15% clay=

loam





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